Remarks/Arguments

Claims 1-22 remain pending. No claims are amended by this response.

Embodiments in accordance with the present invention relate to formation of a refractory metal nucleation layer over a barrier, through alternating exposure to silicon-containing and refractory metal-containing gases. In order to control the thickness of the refractory metal nucleation layer, multiple cycles of such alternating exposure to silicon- and refractory metal-containing gases can be employed.

During the alternating exposure process, the silicon- or refractory metal-containing gas is purged from the chamber after respective exposure of the semiconductor workpiece. (Page 7, lines 13-20). Purging of gases between these processing steps avoids inefficiencies associated with having to change the pressure within the chamber, as would otherwise be necessary to suppress unwanted particle formation:

> by avoiding the simultaneous presence of WF_6 and SiH_4 in the process chamber, gas phase nucleation and hence particle formation is avoided even though the process is conducted at a relatively high pressure. (Emphasis added; page 8, lines 27-29)
>
> * * *
>
> since the pressure employed for formation of the tungsten nucleation layer can be relatively high, tungsten nucleation layer formation processes according to the present invention can be combined with a conventional tungsten CVD reaction (e.g., H_2 reduction of WF_6) for the formation of a tungsten core layer at a relatively high deposition rate. By running the inventive process and the conventional tungsten CVD reaction at the same pressure, unnecessary pressure cycling is avoided and a high effective throughput attained. (Emphasis added; page 9, lines 1-8)

Accordingly, the pending independent claims recite purging of silicon-containing gas between exposure steps, such that silicon-containing and refractory metal-containing gases are not present in the chamber at the same time during formation of the tungsten nucleation layer.

> 1. A method for the formation of a refractory metal nucleation layer on a semiconductor device substrate, the method comprising:
> . . . exposing the metallic barrier layer to a silicon containing gas to form a layer of silicon on the metallic barrier layer;
> purging the silicon containing gas;

exposing the layer of silicon to a refractory metal containing gas .. .
purging the refractory metal containing gas. . . .

* * *

18. A method for the formation of a tungsten nucleation layer on a semiconductor device substrate, the method comprising:
. . . exposing the TiN barrier layer to silane (SiH_4) to form a layer of silicon on the TiN barrier layer;
purging the silane;
exposing the layer of silicon to tungsten hexaflouride (WF_6) . . .
purging the tungsten hexafluoride . . . .

* * *

21. A method for the formation of a refractory metal nucleation layer on a semiconductor device substrate, the method comprising:
. . . exposing the metallic barrier layer to a silicon containing gas to form a layer of silicon on the metallic barrier layer;
purging the silicon containing gas; and
exposing the layer of silicon to a refractory metal containing gas . . . .

* * *

22. A method for the formation of a tungsten nucleation layer on a semiconductor device substrate, the method comprising:
. . . exposing the TiN barrier layer to silane (SiH_4) . . .
purging the silane;
exposing the layer of silicon to tungsten hexaflouride (WF_6) . . .
purging the WF_6 . . . . (Emphasis added)

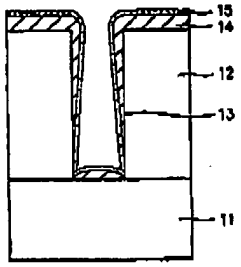
The Examiner has maintained rejection of pending claims 1-22 as obvious under 35 U.S.C. 103 by U.S. Patent No. 6,287,964 to Cho ("the Cho patent"), taken either alone or in combination with U.S. Patent No. 6,107,200 to Takagi et al. ("the Takagi patent") and U.S. Patent No. 6,498,399 to Chung et al. ("the Chung patent"). These claim rejections are traversed as follows.

As a threshold matter, the Examiner is reminded that in order to establish a prima facie case of obviousness, "the prior art reference (or references when combined) must teach or suggest all the claim limitations." MPEP 706.02(j). Here, the references relied upon fail to teach, or even suggest, the limitations of the pending claims.

The Cho patent is the primary reference relied upon by the Examiner.

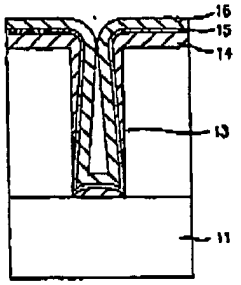
Like the instant application, the Cho patent describes formation of refractory metal layer (Tungsten) over a barrier, utilizing a multi-step process that includes formation of a nucleation layer. However, unlike the instant application, the Cho patent fails to teach or even suggest a process wherein silicon- and refractory metal-containing gases are purged after each step.

In the step of the Cho patent described in connection with Figure 2C (reproduced below), an amorphous silicon layer is deposited over a barrier:



> the reaction path is SiH_4 (gas) -> amorphous Si + $2H_2$ (gas). The amorphous silicon layer 15 is formed on the sides of the ILD layer 12 at the bottom of the contact hole 13 where the barrier metal layer 14 will not form, and at the corner portion of the bottom of the contact hole 13. (Emphasis added; col. 4, lines 35-40)

In the following step described in connection with Figure 2D (reproduced below), the tungsten nucleation layer is formed over the amorphous silicon layer:



> As shown in FIG. 2D, SiH_4 gas and WF_6 gas flow on the amorphous silicon layer 15, and a first tungsten layer 16 is deposited on the amorphous

> silicon layer 15. The reaction path is $3SiH_4$ (gas) + $2WF_6$2W + $3SiF_4$ (gas) + $6H_2$ (gas). (Emphasis added; col. 4, lines 42-46)

The Cho patent thus teaches that the reaction mechanisms for both forming the amorphous silicon (Figure 2C), and the overlying tungsten (Figure 2D), each require the presence of a silicon-containing gas (SiH_4) as a reactant.

The Examiner has relied upon the Cho patent as teaching formation of a tungsten nucleation layer, where silicon-containing gas used to form an amorphous silicon layer is purged prior to exposing the amorphous silicon to a tungsten containing gas. (Office Action Mailed September 29, 2003, page 2, line 14). The particular passage of the Cho patent relied upon for this proposition is reproduced below:

> amorphous silicon layer 15 and the first tungsten layer 16 can be formed by first introducing SiH_4 gas into the reaction chamber for a period of time necessary to form the amorphous silicon layer 15, then also introducing the WF_6 gas to form the first tungsten layer 16. (Emphasis added; col. 4, lines 46-50)

The Examiner has somehow construed this passage to teach or suggest a two step process wherein only the tungsten-containing gas is present during the second step. As described in detail below, there is no support for the Examiner's reading of the Cho patent.

The mechanism for chemical vapor deposition of amorphous silicon described in the Cho patent (Figure 2C), as well as the mechanism for subsequent deposition of tungsten described in the Cho patent (Figure 2D), each requires the presence of a silicon-containing gas (SiH_4) as a reactant. Accordingly, the above-referenced passage of the Cho patent can be read to suggest performing the sequential deposition of amorphous silicon and tungsten utilizing an uninterrupted flow of silicon-containing gas.

Neither the above-cited passage, nor indeed any other portion of the Cho patent, can legitimately be read to teach, or even suggest, purging of silicon containing gas in accordance with the pending claims. Such an absence of teaching by the Cho patent is not surprising, given that this reference fails to recognize the issue of unwanted particle formation resulting in the absence of such purging steps. In fact, the Cho patent fails even to mention specific pressures at which the amorphous silicon and tungsten nucleation layer deposition steps take place.

The remaining patents relied upon by the Examiner also fail to teach or suggest a process flow preventing the simultaneous presence of silicon- and refractory metal-containing gases within the chamber.

The Chung patent relates only generally to formation of barrier layers comprising different materials such as titanium or tantalum. This patent does not teach or even suggest a process for forming tungsten over such barrier layers in a manner which avoids the simultaneous presence of silicon containing and refractory metal containing gases in the processing chamber.

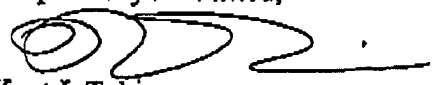
The Takagi patent relied upon by the Examiner focuses upon formation of a Tungsten layer utilizing diborane as a reducing agent. In each case where a silicon containing gas (monosilane) is described as being flowed into the chamber, it is accompanied by a tungsten containing gas. (See col. 5, lines 30-32; col. 4, line 67 - col. 6, line 2; col. 6, lines 20-22; col. 6, lines 55-56; and col. 9, lines 48-60).

Moreover, the simultaneous flow of silicon and tungsten containing gases taught by the Takagi patent, is performed at a substantially lower pressure (3 Torr) than subsequent processing (80 Torr). Such a dramatic pressure change would undesirably degrade throughput. Implementation of such a low pressure step, notwithstanding its resulting impact on throughput, is evidence of the Takagi patent's attempt to avoid particle formation due to the simultaneous presence of silicon-containing and tungsten-containing gases at higher pressures. The Takagi patent thus adopts the conventional approach, and certainly cannot be viewed as suggesting the gas purging of the pending claims.

Because none of the patents relied upon by the Examiner describe or even suggest a process in which silicon containing gases and refractory metal containing gases are purged to avoid their simultaneous presence within the processing chamber, it is respectfully asserted that the pending claims are not anticipated or obvious in view of these references.

Applicant believes all claims now pending in this Application are in condition for allowance. Issuance of a formal Notice of Allowance at an early date is thus respectfully requested. If the Examiner believes a telephone conference would expedite prosecution of this application, please telephone the undersigned at (650) 326-2400 x5423.

Respectfully submitted,



Kent J. Tobin
Reg. No. 39,496

TOWNSEND and TOWNSEND and CREW LLP
Tel: (650) 326-2400
Fax: (650) 326-2422
KJT:km
PA 3315017 v1